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# Technical and Scale Efficiency of the Paddy Cultivation in India

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**Abstract:**

Agriculture is the Key sector in the economy of any nation. Its contribution towards employment, food security and Gross Domestic Product needs emphasis on its production and consumption. In this light, this paper analyses the technical efficiency of paddy production among Indian states using Data Envelopment Analysis technique. The output variable used in this paper is the produced quantity of paddy. Input variables are related to Land used, Fertilizers consumed and area treated with pesticides. This analysis from an input orientation observes that 25% of the states are technically efficient under Constant Returns to Scale assumption and 55% states are technically efficient under Variable Returns to Scale assumption. 25% states are scale efficient. 35% of states operate under Decreasing Returns to Scale and 40% under Increasing Returns to scale. The average scale efficiency of the 15 inefficient firms is found to be 83% suggesting a 17% reduction of the resources used by them to keep output levels constant. Besides, this paper also summarises the results from both input-oriented technical efficiency and output-oriented technical efficiency measures. Furthermore, these measures are reported for the production characterized by Constant Returns to Scale and Variable Returns to Scale. Madhya Pradesh, Gujarat, Telangana, Andhra Pradesh, Telangana and Tamil Nadu form the technically inefficient group either from an input-oriented or from output-oriented measures of technical efficiency. Both the orientations are useful from the policy perspectives of food security, environmental conservation and reduced burden on the public exchequer.

**Keywords –** Data Envelopment Analysis, Efficiency, Food Security, Productivity, Returns to Scale

## Introduction

Indian agriculture is a significant producer of wide range of food grains in the world indicating the concerns of food security (Mohapatra et al., 2023). Besides, it is the largest livelihood provider in India and majority of them are marginal and small farmers. The role of agriculture in the Gross Domestic Product of India can be no easily ignored (Ansari et al., 2022). Agriculture is one of the environmentally damaging sectors in the form of deforestation, biodiversity loss, water pollution, Land use change and excessive draft of available water sources. Within agriculture, the production of paddy poses several climatic and non-climatic threats. For instance, Paddy is the most water intensive crop compared to other cereal crops, a significant contributor of greenhouse gas emissions (Mote et al., 2020). Due to these reasons, it makes an important case to dwell upon the production aspects of the paddy. (Pradhan, 2018) analyses the input oriented technical efficiency of rice production in Odisha of India focusing on the seeds, fertilizers and annual rainfall as inputs. (K. S.r., 2020) analysed the production of rice in case of Andhra Pradesh of India, similarly (N. S. Chauhan et al., 2006) in West Bengal of India, (Nassiri & Singh, 2009) in Punjab of India focusing on energy inputs, (Kalli et al., 2024) in the tribal districts of Eastern India, and (Umanath & Rajasekar, 2013) in the Madurai District of Tamil Nadu, India. The purpose of this study is to conduct a macro-level study to analyse the technical efficiency of paddy production among Indian states. The analysis of technical efficiency for a single crop and also geographically diversified is evident from the following literature. (Wei et al., 2020) analysed the efficiency for cotton crop, (Hosseinzadeh-Bandbafha et al., 2018) for peanut, (Ebrahimi & Salehi, 2015) for Mushroom, (Mousavi-Avval et al., 2011) for soybean, (Avval et al., 2011) for sunflower, (Banaeian et al., 2012) for strawberry, (Masuda, 2016) for wheat, (Mushtaq et al., 2021) for tobacco, and (Khoshroo et al., 2021) for tomato. In line with this, the present study used Gross Cropped area, Diammonium phosphate (DAP), Urea, Potash, Area treated with pesticides as inputs solely dedicated to produce paddy in each state of India. Fertilizers and pesticides are essential and costly inputs in the paddy production (Mairghany et al., 2022). Chemical fertilizers enhance crop growth by artificially supplementing nutrients and pesticides prevent, kill pests that are harmful for agricultural production. In current times, use of chemical fertilizers and pesticides became indispensable to ensure sustainable crop yields but fraught with adverse effects of soil acidification, reducing the fertility of soil, eutrophication of surface water bodies, pollution of groundwater from consumption side and requires precious mineral minerals such as coal, petroleum to produce them (Zhan et al., 2021), besides impacting public health and biodiversity(ul Haq et al., 2020). Bio pesticides and Bio fertilisers are the suggested sustainable transitions to this problem in India (Paul et al., 2023), However, their uptake is still miniscule in comparison to chemical pesticides and fertilisers (Mishra et al., 2020). India occupies an important position both in area and production of rice (Mahajan et al., 2017). Considering the food security of the nation, about 65 percent of the population of India consumes rice as the staple food (Ahmad, 2021). A sizeable portion of the budget is dedicated to the agriculture as part of subsidy (Gulati & Banerjee, 2015). This study aims to analyse the technical efficiency of paddy production in India both from an input orientation to the effect of rational use of the key inputs and from an output orientation to address the problem of food security.

## DATA and METHODOLOGY

The source of the data used in this study is secondary. The important variables used for the conduct of this study are paddy produced, Diammonium Phosphate, Gross Cropped Area, Urea, Potash and Area treated with pesticides in each state of India. Data on these variables is collected from the All-India Report on Input Survey 2016-2017. The units of area are measured in hectares and the quantities are measured in Kilograms. The input survey provides useful information on the usage of key agricultural inputs such as types of seeds, chemical fertilizers, organic manure, machinery, institutional credit, pest management practices and soil testing facilities (DAC&FW, 2021). The data used for this paper is shown in Table 1 and reported in section IV. Coming to the methodology, this paper analyses the technical efficiency of paddy production among Indian states using a non-parametric method for analysing the production called Data Envelopment Analysis (DEA). Data Envelopment Analysis is a linear programming based technique to evaluate the relative efficiency measures of similar Decision Making Units (DMUs) with identical inputs and outputs (Pakravan-Charvadeh et al., 2022). This technique is widely applied to DMUs belonging to several sectors of the economy such as agriculture, banking, sports, transportation, education, communication, fishery, tourism, healthcare, automobile, forestry, water, real estate, E-business, software but not limited to (Panwar et al., 2022). It is essential to optimize paddy production efficiency by achieving the output through minimum input. This can be envisaged through better output for a given level of input (output oriented) or by minimizing the level of input for a specified level of output (input oriented). This study analyses from both the orientations. The rule of thumb in DEA analysis is the number of DMUs must exceed thrice the sum of number of inputs and outputs (Wong, 2021). The present study also circumvents this problem.

### EQUATIONS

The present study uses one output and five inputs. Using these we evaluate the relative efficiencies of DMUs in two orientations under two basic DEA models namely CCR and BCC models.
The input-oriented model used under Constant Returns to Scale assumption for a hypothetical DMU **‘k’** is presented as:

$Min\theta$

**Subject to:** $\sum_{j=1}^{20} \lambda_j y_j \geq y_k$

$\sum_{j=1}^{20} \lambda_j x_{1j} \leq \theta x_{1k}$

$\sum_{j=1}^{20} \lambda_j x_{2j} \leq \theta x_{2k}$ ………………………………………………………………. **(1)**

**……..**

**……..**

$\sum_{j=1}^{20} \lambda_j x_{5j} \leq \theta x_{5k}$

$\theta$ **free,** $\lambda_j \geq 0$ **(j=1, 2….20)**

The output-oriented model used under Constant Returns to Scale assumption for a hypothetical DMU **‘k’** is presented as:

$Max\ \varphi$

**Subject to:** $\sum_{j=1}^{20} \mu_j y_j \geq \varphi y_k$

$\sum_{j=1}^{20} \mu_j x_{1j} \leq x_{1k}$

$\sum_{j=1}^{20} \mu_j x_{2j} \leq x_{2k}$ ……………………………………………………………… **(2)**

**……..**

**……..**

$\sum_{j=1}^{20} \mu_j x_{5j} \leq x_{5k}$

$\varphi$ **free,** $\mu_j \geq 0$ **(j=1, 2….20)**

The input-oriented model used under Variable Returns to Scale assumption for a hypothetical DMU **'k'** is presented as:

$Min\theta$

**Subject to:** $\sum_{j=1}^{20} \lambda_j y_j \geq y_k$

$\sum_{j=1}^{20} \lambda_j x_{1j} \leq \theta x_{1k}$

$\sum_{j=1}^{20} \lambda_j x_{2j} \leq \theta x_{2k}$ ……………………………………………………………… **(3)**

**……..**

**……..**

$\sum_{j=1}^{20} \lambda_j x_{5j} \leq \theta x_{5k}$

$\sum_{j=1}^{20} \lambda_j = 1$

$\theta$ **free,** $\lambda_j \geq 0$ **(j=1, 2….20)**

The output-oriented model used under Variable Returns to Scale assumption for a hypothetical DMU **'k'** is presented as:

$Max\ \varphi$

**Subject to:** $\sum_{j=1}^{20} \mu_j y_j \geq \varphi y_k$

$\sum_{j=1}^{20} \mu_j x_{1j} \leq x_{1k}$

$\sum_{j=1}^{20} \mu_j x_{2j} \leq x_{2k}$ ……………………………………………………………… **(4)**

**……..**

**……..**

$\sum_{j=1}^{20} \mu_j x_{5j} \leq x_{5k}$

$\sum_{j=1}^{20} \mu_j = 1$

$\varphi$ **free,** $\mu_j \geq 0$ **(j=1, 2….20)**

The input-oriented model used under Non-Increasing Returns to Scale assumption for a hypothetical DMU **'k'** is presented as:

$Min\theta$

**Subject to:** $\sum_{j=1}^{20} \lambda_j y_j \geq y_k$

$\sum_{j=1}^{20} \lambda_j x_{1j} \leq \theta x_{1k}$

$\sum_{j=1}^{20} \lambda_j x_{2j} \leq \theta x_{2k}$ ……………………………………………………………… **(5)**

**……..**

**……..**

$\sum_{j=1}^{20} \lambda_j x_{5j} \leq \theta x_{5k}$

$\sum_{j=1}^{20} \lambda_j \leq 1$

$\theta$ **free,** $\lambda_j \geq 0$ **(j=1, 2….20)**

Please note that these are the models for evaluating the technical efficiency for a hypothetical firm. This step is to be repeated for each DMU in the sample.

**Figures and Tables**

**Table 1 The inputs and Output data of paddy production among Indian states**

| DMU | GCA | DAP | UREA | POT | ATP | PRODUCTION |
|---|---|---|---|---|---|---|
| Andhra Pradesh | 261590000 | 329762000 | 665008000 | 125655000 | 1697400 | 7452400000 |
| Assam | 2599000 | 21798000 | 276254000 | 34652000 | 610600 | 4727400000 |
| Bihar | 3900500 | 119283000 | 818398000 | 36490000 | 1248600 | 8239300000 |
| Chhattisgarh | 4298400 | 234279000 | 549332000 | 39568000 | 645500 | 8048400000 |
| Gujarat | 3400600 | 42364000 | 357502000 | 10618000 | 760100 | 1930000000 |
| Haryana | 1934000 | 193482000 | 455965000 | 5736000 | 1360900 | 4453000000 |
| Jammu&Kashmir | 243500 | 11518000 | 20457000 | 1950000 | 114200 | 572200000 |
| Karnataka | 1355900 | 113894000 | 226267000 | 43918000 | 463100 | 2604800000 |
| Kerala | 157500 | 2354000 | 27451000 | 9394000 | 92500 | 437100000 |
| Madhya Pradesh | 5146800 | 206847000 | 520302000 | 25705000 | 1470700 | 4226800000 |
| Maharashtra | 1585100 | 24743000 | 132875000 | 6762000 | 512200 | 3109500000 |
| Odisha | 4387400 | 1086353000 | 171843000 | 58113000 | 1189200 | 8325900000 |
| Punjab | 2928100 | 114433000 | 677239000 | 3432000 | 1414900 | 11586200000 |
| Rajasthan | 219500 | 20294000 | 49658000 | 1364000 | 93300 | 452700000 |
| Tamil Nadu | 2166800 | 227797000 | 438633000 | 79047000 | 543100 | 2369400000 |
| Telangana | 2371500 | 345702000 | 498858000 | 100293000 | 2138500 | 5173400000 |
| Tripura | 217700 | 464000 | 13805000 | 1751000 | 138300 | 814600000 |
| Uttar Pradesh | 14577300 | 903720000 | 2342359000 | 101377000 | 2317300 | 13754000000 |
| Uttarakhand | 338000 | 11473000 | 78288000 | 4358000 | 142100 | 630000000 |
| West Bengal | 6202000 | 147412000 | 709581000 | 124912000 | 4483200 | 15302500000 |

**Table 2 shows the results obtained for an input oriented constant returns to scale model**

| DMU | Score | Rank | Peer Group |
|---|---|---|---|
| Andhra Pradesh | 0.51724 | 17 | Chhattisgarh (0.523971); Odisha (0.042499); Tripura (3.537232) |
| Assam | 1 | 1 | Assam (1) |
| Bihar | 0.778364 | 7 | Assam (0.444444); Chhattisgarh (0.145569); Punjab (0.428668) |
| Chhattisgarh | 1 | 1 | Chhattisgarh (1) |
| Gujarat | 0.334314 | 20 | Assam (0.070773); Punjab (0.108606); Tripura (0.413817) |
| Haryana | 0.58189 | 12 | Punjab (0.384337) |
| Jammu&Kashmir | 0.763386 | 8 | Chhattisgarh (0.012847); Punjab (0.001278); Tripura (0.557324) |
| Karnataka | 0.649102 | 10 | Chhattisgarh (0.09596); Punjab (0.131219); Tripura (0.383192) |
| Kerala | 0.727182 | 9 | Punjab (0.013565); Tripura (0.343638) |
| Madhya Pradesh | 0.369727 | 19 | Chhattisgarh (0.142716); Punjab (0.128523); Tripura (1.95073) |

| | | | |
|---|---|---|---|
| Maharashtra | 0.869718 | 6 | Assam (0.008033); Chhattisgarh (0.042676); Punjab (0.090809); Tripura (2.057348) |
| Odisha | 1 | 1 | Odisha (1) |
| Punjab | 1 | 1 | Punjab (1) |
| Rajasthan | 0.574025 | 13 | Chhattisgarh (0.005119); Punjab (0.035517) |
| Tamil Nadu | 0.437178 | 18 | Chhattisgarh (0.153894); Punjab (0.097599) |
| Telangana | 0.555074 | 14 | Punjab (0.393501); Tripura (0.754015) |
| Tripura | 1 | 1 | Tripura (1) |
| Uttar Pradesh | 0.530291 | 16 | Chhattisgarh (1.336199); Punjab (0.258906) |
| Uttarakhand | 0.539875 | 15 | Assam (0.013388); Chhattisgarh (0.00197); Punjab (0.047544) |
| West Bengal | 0.648078 | 11 | Punjab (0.417006); Tripura (12.854145) |

**Table 3 shows the results obtained for an output oriented constant returns to scale model**

| DMU | Score | Rank | Peer Group |
|---|---|---|---|
| Andhra Pradesh | 0.51724 | 17 | Chhattisgarh (1.013013); Odisha (0.082166); Tripura (6.838672) |
| Assam | 1 | 1 | Assam (1) |
| Bihar | 0.778364 | 7 | Assam (0.570998); Chhattisgarh (0.187019); Punjab (0.55073) |
| Chhattisgarh | 1 | 1 | Chhattisgarh (1) |
| Gujarat | 0.334314 | 20 | Assam (0.211695); Punjab (0.324864); Tripura (1.237812) |
| Haryana | 0.58189 | 12 | Punjab (0.660497) |
| Jammu&Kashmir | 0.763386 | 8 | Chhattisgarh (0.016829); Punjab (0.001674); Tripura (0.730069) |
| Karnataka | 0.649102 | 10 | Chhattisgarh (0.147835); Punjab (0.202154); Tripura (0.590342) |
| Kerala | 0.727182 | 9 | Punjab (0.018655); Tripura (0.472562) |
| Madhya Pradesh | 0.369727 | 19 | Chhattisgarh (0.386005); Punjab (0.347617); Tripura (5.27614) |
| Maharashtra | 0.869718 | 6 | Assam (0.009236); Chhattisgarh (0.049069); Punjab (0.104412); Tripura (2.365534) |
| Odisha | 1 | 1 | Odisha (1) |
| Punjab | 1 | 1 | Punjab (1) |
| Rajasthan | 0.574025 | 13 | Chhattisgarh (0.008917); Punjab (0.061873) |
| Tamil Nadu | 0.437178 | 18 | Chhattisgarh (0.352017); Punjab (0.223248) |
| Telangana | 0.555074 | 14 | Punjab (0.708916); Tripura (1.358404) |
| Tripura | 1 | 1 | Tripura (1) |
| Uttar Pradesh | 0.530291 | 16 | Chhattisgarh (2.519748); Punjab (0.488234) |
| Uttarakhand | 0.539875 | 15 | Assam (0.024799); Chhattisgarh (0.003649); Punjab (0.088064) |
| West Bengal | 0.648078 | 11 | Punjab (0.64345); Tripura (19.834243) |

**Table 4 shows the results obtained for an input-oriented variable returns to scale model**

| DMU | Score | Rank | Peer Group |
|---|---|---|---|
| Andhra Pradesh | 0.572565 | 16 | Maharashtra (0.275028); Odisha (0.117362); Punjab (0.475797); Tripura (0.131813) |
| Assam | 1 | 1 | Assam (1) |
| Bihar | 0.778771 | 13 | Assam (0.415154); Chhattisgarh (0.141172); Punjab (0.443673) |
| Chhattisgarh | 1 | 1 | Chhattisgarh (1) |
| Gujarat | 0.34718 | 20 | Assam (0.032229); Chhattisgarh (0.019641); Punjab (0.078652); Tripura (0.869477) |

| | | | |
|---|---|---|---|
| Haryana | 0.585942 | 15 | Punjab (0.337777); Tripura (0.662223) |
| Jammu Kashmir | 1 | 1 | Jammu Kashmir (1) |
| Karnataka | 0.674414 | 14 | Chhattisgarh (0.108949); Punjab (0.09303); Tripura (0.798021) |
| Kerala | 1 | 1 | Kerala (1) |
| Madhya Pradesh | 0.392777 | 19 | Maharashtra (0.273011); Odisha (0.044394); Punjab (0.227655); Tripura (0.45494) |
| Maharashtra | 1 | 1 | Maharashtra (1) |
| Odisha | 1 | 1 | Odisha (1) |
| Punjab | 1 | 1 | Punjab (1) |
| Rajasthan | 1 | 1 | Rajasthan (1) |
| Tamil Nadu | 0.474427 | 18 | Chhattisgarh (0.185385); Punjab (0.019845); Tripura (0.79477) |
| Telangana | 0.561344 | 17 | Odisha (0.007345); Punjab (0.399535); Tripura (0.59312) |
| Tripura | 1 | 1 | Tripura (1) |
| Uttar Pradesh | 1 | 1 | Uttar Pradesh (1) |
| Uttarakhand | 0.801152 | 12 | Chhattisgarh (0.004481); Kerala (0.22407); Rajasthan (0.365928); Tripura (0.40552) |
| West Bengal | 1 | 1 | West Bengal (1) |

**Table 5 shows the results obtained for an output-oriented variable returns to scale model**

| DMU | Score | Rank | Peer Group |
|---|---|---|---|
| Andhra Pradesh | 0.629529 | 15 | Odisha (0.030235); Punjab (0.87547); West Bengal (0.094295) |
| Assam | 1 | 1 | Assam (1) |
| Bihar | 0.783488 | 12 | Assam (0.096614); Chhattisgarh (0.115146); Punjab (0.78824) |
| Chhattisgarh | 1 | 1 | Chhattisgarh (1) |
| Gujarat | 0.367284 | 20 | Assam (0.253143); Punjab (0.320258); Tripura (0.4266) |
| Haryana | 0.583199 | 16 | Punjab (0.633228); Tripura (0.366772) |
| Jammu Kashmir | 1 | 1 | Jammu Kashmir (1) |
| Karnataka | 0.651793 | 14 | Chhattisgarh (0.149343); Punjab (0.195091); Tripura (0.655566) |
| Kerala | 1 | 1 | Kerala (1) |
| Madhya Pradesh | 0.426339 | 19 | Maharashtra (0.191142); Odisha (0.109923); Punjab (0.616429); West Bengal (0.082506) |
| Maharashtra | 1 | 1 | Maharashtra (1) |
| Odisha | 1 | 1 | Odisha (1) |
| Punjab | 1 | 1 | Punjab (1) |
| Rajasthan | 1 | 1 | Rajasthan (1) |
| Tamil Nadu | 0.446902 | 18 | Chhattisgarh (0.362753); Punjab (0.172969); Tripura (0.464278) |
| Telangana | 0.579226 | 17 | Odisha (0.048853); Punjab (0.719487); Tripura (0.23166) |
| Tripura | 1 | 1 | Tripura (1) |
| Uttar Pradesh | 1 | 1 | Uttar Pradesh (1) |
| Uttarakhand | 0.666664 | 13 | Chhattisgarh (0.03219); Kerala (0.186317); Rajasthan (0.08874); Tripura (0.692753) |
| West Bengal | 1 | 1 | West Bengal (1) |

**Table 6 shows the scale efficiency of DMUs**

| TEI CRS | TEI VRS | TEI NIRS | SE | RTS |
|---|---|---|---|---|
| 0.51724 | 0.572565 | 0.572565 | 0.903373 | DRS |
| 1 | 1 | 1 | 1 | CRS |
| 0.778364 | 0.778771 | 0.778771 | 0.999477 | DRS |
| 1 | 1 | 1 | 1 | CRS |
| 0.334314 | 0.34718 | 0.334314 | 0.962941 | IRS |
| 0.58189 | 0.585942 | 0.58189 | 0.993085 | IRS |
| 0.763386 | 1 | 0.763386 | 0.763386 | IRS |
| 0.649102 | 0.674414 | 0.649102 | 0.962468 | IRS |
| 0.727182 | 1 | 0.727182 | 0.727182 | IRS |
| 0.369727 | 0.392777 | 0.392777 | 0.941315 | DRS |
| 0.869718 | 1 | 1 | 0.869718 | DRS |
| 1 | 1 | 1 | 1 | CRS |
| 1 | 1 | 1 | 1 | CRS |
| 0.574025 | 1 | 0.574025 | 0.574025 | IRS |
| 0.437178 | 0.474427 | 0.437178 | 0.921486 | IRS |
| 0.555074 | 0.561344 | 0.561344 | 0.98883 | DRS |
| 1 | 1 | 1 | 1 | CRS |
| 0.530291 | 1 | 1 | 0.530291 | DRS |
| 0.539875 | 0.801152 | 0.539875 | 0.673873 | IRS |
| 0.648078 | 1 | 1 | 0.648078 | DRS |

## Conclusion

Above 60 percent of India's Population consume rice as the staple food. Since land is a fixed resource, one can increase the output only through increasing productivity of the inputs. This study analysed the technical efficiency of the paddy cultivation among Indian states. The results indicate that from an input-oriented CRS model, Chhattisgarh, Assam, Odisha, Punjab and Tripura are technical efficient DMUs while the technically inefficient DMUs are ordered as Gujarat, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, and Uttar Pradesh. Each of these technically inefficient DMUs, even after achieving technical efficiency with respect to their peer group still have the potential to reduce the inputs although not all the inputs. These are called input slacks. Input slacks and Output slacks arise since CRS and VRS measures of technical efficiency are radial measures. For Gujarat, even without reducing its current output, even after reducing all its inputs to 33.4 percent of its current level of inputs, it can still reduce the use of 544.9 thousand hectares of Gross Cropped Area and 20701.4 Metric Tons of Urea to produce Paddy. Two states fall in the inefficient category where their current level of inputs is to be reduced by 60-70 percent. Similarly, one state in the 50-60 percent, six states in the 40-50 percent, and two states in the 30-40 percent. Under VRS assumption, Assam, Chhattisgarh, Jammu and Kashmir, Kerala, Maharashtra, Odisha, Punjab, Rajasthan, Tripura, Uttar Pradesh, West Bengal are the efficient DMUs, whereas the Inefficient DMUs are ordered as Gujarat, Madhya Pradesh, Tamil Nadu, Telangana, and Andhra Pradesh. Since the input-oriented and output-oriented technical efficiency measures are identical under CRS, the output-oriented VRS model identifies Assam, Chhattisgarh, Jammu and Kashmir, Kerala, Maharashtra, Odisha, Punjab, Rajasthan, Tripura, Uttar Pradesh, West Bengal as technically efficient DMUs while the inefficient DMUs are ordered as Gujarat, Madhya Pradesh, Tamil Nadu, Telangana and Haryana. Given the DMUs, inputs and output considered in this study, the efficient production of paddy for the whole of India is discussed as follows. Given the production of paddy, from an input-oriented CRS model, there is a potential for reduction of 280626.2 thousand of hectares of Gross Cropped Area dedicated for paddy with highest contribution towards it from Andhra Pradesh, Uttar Pradesh, Madhya Pradesh and Gujarat, 1765307.3 Metric Tons of DAP with highest contribution from Uttar Pradesh, Telangana, Tamil Nadu and Andhra Pradesh, 3800515.5 Metric Tons of Urea with highest contribution from Uttar Pradesh, Madhya Pradesh, Bihar and Andhra Pradesh, 510419.8 Metric Tons of Potash with highest contribution from West Bengal, Telangana, Andhra Pradesh, and Tamil Nadu, and 8720.4 thousands of hectares treated with pesticides with highest contribution from West Bengal, Telangana, Uttar Pradesh and Madhya Pradesh. Similarly, from an input-oriented VRS model, there is a potential for reduction of 27023.5 thousand of hectares of Gross Cropped Area dedicated for paddy with highest contribution towards it from Andhra Pradesh, Madhya Pradesh, Gujarat and Tamil Nadu, 1028208.6 Metric Tons of DAP with highest contribution from Telangana, Tamil Nadu, Haryana, and Andhra Pradesh, 2085994.4 Metric Tons of Urea with highest contribution from Bihar, Madhya Pradesh, Tamil Nadu and Andhra Pradesh, 366622 Metric Tons of Potash with highest contribution from Andhra Pradesh, Telangana, Tamil Nadu and Karnataka, and 5129.3 thousands of hectares treated with pesticides with highest contribution from Telangana, Madhya Pradesh, Haryana, and Andhra Pradesh. The analysis from an input orientation observes that 25% of the states are technically efficient under Constant Returns to Scale assumption and 55% states are technically efficient under Variable Returns to Scale Assumption. 25% of states are scale efficient. 35% of states operate under Decreasing Returns to Scale and 40% states operate under Increasing Returns to scale. The average scale efficiency of the 15 inefficient firms is found to be 83%, suggesting a 17% reduction of the resources used by them to keep output levels constant. Scale inefficient states whose projections onto the VRS frontier falls under increasing returns to scale portion must expand both its inputs and outputs to operate at Most Productive Scale Size (MPSS). Similarly states those are operating under diminishing returns to scale must reduce its outputs and inputs as well (Dash et al., 2010). Concerning the food security of the nation, the output-oriented measure under CRS assumption reveal that, given the inputs used, there must be an increase of 54327463 Metric Tons of Paddy production to be efficient. To achieve this, the highest contribution from Uttar Pradesh, West Bengal, Madhya Pradesh and Andhra Pradesh is expected. Similarly, under VRS assumption given the inputs used there must be an increase of 54327463 Metric Tons of Paddy production to the production of paddy to be efficient with highest contributions from Madhya Pradesh, Andhra Pradesh, Telangana and Gujarat. The present study is useful in identifying the inefficient DMUs based on which policy can be framed. Meticulously seen, Madhya Pradesh, Gujarat, Telangana, Andhra Pradesh, Telangana and Tamil Nadu are the hotspots to act upon either from an input-oriented policy or from an output-oriented one. Further this study is capitalized on the individual inputs within the category of fertilizers to rationalize their use and to reduce the burden on the public exchequer. The key limitation of this study is not considering Jharkhand state, India as one of the DMUs. This is due to the lack of data on it. This study has the potential to address emerging challenges in the light of integrated natural resources, namely water, energy and food. Their production and consumption aspects of them can be considered as a nexus between them. The current analysis in this paper can be considered as a contribution from a water-energy-food nexus perspective provided data on irrigation is available. Unfortunately, India does not follow a volumetric pricing of water. In this light, few studies considered mean annual rainfall as an input in the production process, but it cannot be considered as an input because it is an exogenous factor. To account on such aspect, a study based on primary data may be conducted from a water-energy-food nexus perspective and provide a microscopic view of the paddy production for a given geography.

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